PATENT ABSTRACTS OF JAPAN

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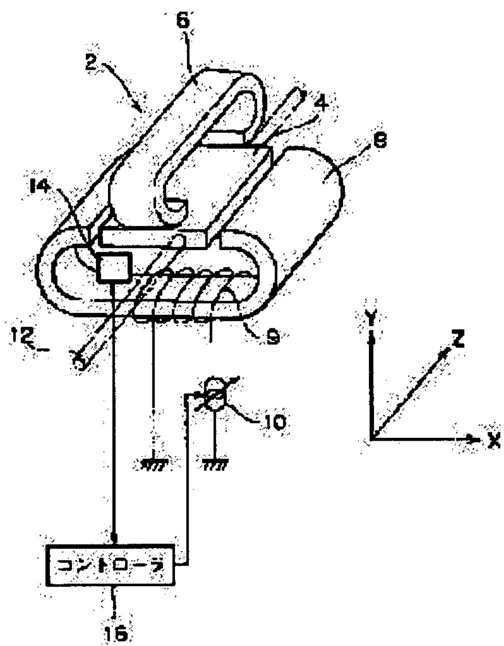
(54) FARADAY ROTATOR AND OPTICAL DEVICE USING THE SAME FARADAY ROTATOR

(57)Abstract:
PROBLEM TO BE SOLVED: To provide the Faraday rotator which can hold the Faraday rotational angle always constant irrelevantly to temperature variation.
SOLUTION: The Faraday rotator 2 includes magnetooptic crystal 4 provided in the propagation path of light, a permanent magnet 6 which produces a magnetic field parallel to the propagation direction of the light, and an electromagnet 8 which produces a magnetic field orthogonally to the light propagation direction. The intensity of the composite magnetic field of the permanent magnet 6 and electromagnet 8 is set large enough to magnetically saturate the magnetooptic crystal 4. The electromagnet 8 is driven by a driving circuit 10. The Faraday rotator 2 further includes a temperature sensor 14 provided adjacently to the Faraday rotator 2 and a controller 16 which has data on the temperature dependency of the Faraday rotational angle of the magnetooptic crystal inside and controls the driving circuit 10 according to the detected temperature of the temperature sensor so that the Faraday rotational angle becomes constant.



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* NOTICES *

CLAIMS

[Claim(s)]
[Claim 1] The magneto optics crystal which is a Faraday-rotation child and was prepared in the propagation path of light; the 1st and 2nd mutually different magnetic fields of a direction Impress to the aforementioned magneto optics crystal so that synthetic magnetic field strength may exceed a predetermined value. The data of the temperature dependence of the Faraday-rotation angle of a temperature sensor and the; aforementioned magneto optics crystal adjoined and prepared for the magnetic field impression means containing the electromagnet which generates either the above 1st or the 2nd magnetic field at least, the driving means which drive the; aforementioned electromagnet, and the; aforementioned Faraday-rotation child are built in. The Faraday-rotation child characterized by providing the control means which control the aforementioned driving means so that a Faraday-rotation angle becomes fixed according to the detection temperature of the aforementioned temperature sensor, and;.
[Claim 2] The aforementioned magnetic field impression means is a Faraday-rotation child containing the permanent magnet which generates another side of the above 1st and the 2nd magnetic field according to claim 1.
[Claim 3] The above 1st and the 2nd magnetic field are a Faraday-rotation child according to claim 2 impressed in the direction which intersects perpendicularly mutually in a flat surface including the propagation direction of the aforementioned light.
[Claim 4] The magnetic field by the aforementioned permanent magnet is a Faraday-rotation child according to claim 3 impressed to the propagation direction of the aforementioned light, and parallel.
[Claim 5] The aforementioned temperature sensor is a Faraday-rotation child according to claim 1 who consists of thermistors convertible into current change in a temperature change.
[Claim 6] Have been arranged so that the direction of a magnetic field which is a Faraday-rotation child and is generated to the propagation path of the magneto optics crystal prepared in the propagation path of light and; light may make the 1st angle. Have been arranged so that the direction of a magnetic field generated to the propagation path of the 1st permanent magnet and; light which have the 1st temperature coefficient of magnetic field strength may make the 2nd bigger angle than the 1st angle of the above. The Faraday-rotation angle produced in the light which passes the aforementioned magneto optics crystal by the synthetic magnetic field of the magnetic field which possessed the 2nd permanent magnet which has the 2nd temperature coefficient of bigger magnetic field strength than the 1st temperature coefficient of the above, and was generated by the; above 1st and the 2nd permanent magnet The Faraday-rotation child characterized by being maintained at simultaneously regularity irrespective of a temperature change.
[Claim 7] It is the Faraday-rotation child according to claim 6 by whom the 1st angle of the above is 0 degree, and the 1st permanent magnet of the above is arranged at the propagation direction of light, and parallel.
[Claim 8] The above 1st and the 2nd permanent magnet are a Faraday-rotation child according to claim 7 stationed so that it may intersect perpendicularly mutually on substance.
[Claim 9] The optical device characterized by providing the following. The magneto optics crystal prepared in the propagation path of light. A magnetic field impression means containing the electromagnet which generates either the above 1st or the 2nd magnetic field at least to impress the 1st and 2nd mutually different magnetic fields of a direction to the aforementioned magneto optics crystal so that synthetic magnetic field strength may exceed a predetermined value. Control means and; which were adjoined and prepared for the Faraday-rotation child and the; aforementioned Faraday-rotation child containing the driving means which drive the aforementioned electromagnet and which control the aforementioned driving means so that the data of the temperature dependence of the Faraday-rotation angle of a temperature sensor and the; aforementioned magneto optics crystal convertible into current change are built in and a Faraday-rotation angle becomes fixed according to the detection temperature of the aforementioned temperature sensor about a temperature change.
[Claim 10] The aforementioned optical device is an optical device according to claim 9 which consists of either an

optical isolator, an optical attenuator, an optical switch, an optical circulator and a polarization controller.
[Claim 11] The aforementioned magnetic field impression means contains further the permanent magnet which generates another side of the above 1st and the 2nd magnetic field, and the direction of a magnetic field of the aforementioned permanent magnet is an optical device [parallel to the propagation direction of the aforementioned light] according to claim 9.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] this invention relates to the optical device which used the Faraday-rotation child and the Faraday-rotation child.
[0002] A Faraday-rotation child is a device for controlling the polarization state of light using the Faraday effect that plane of polarization rotates, in case light passes through the inside of a magnetic field parallel to the travelling direction.
[0003]
[Description of the Prior Art] Generally, a Faraday-rotation child consists of a magneto optics crystal which has magnetization, and a magnetic field impression means which consists of permanent magnets or electromagnets for making this magneto optics crystal produce magnetization etc., and the plane of polarization of light rotates by passing light inside the magneto optics crystal which magnetization produced. The angle which plane of polarization rotated is called Faraday-rotation angle by having passed the magneto optics crystal.
[0004] Since a Faraday-rotation child changes a magnetization component parallel to the travelling direction of the light produced inside a magneto optics crystal by controlling the magnetic field impressed by the magnetic field impression means and a Faraday-rotation angle can be controlled, it is mostly used as a controlling element of plane of polarization.
[0005] Various optical devices containing the optical isolator, the optical attenuator, the optical switch, the optical circulator, etc. are realizable by combining a Faraday-rotation child with polarization sensing elements, such as a wavelength plate, a polarizer, a polarization beam splitter, etc.
[0006]
[Problem(s) to be Solved by the Invention] When temperature dependence is in a Faraday-rotation angle and the angle of rotation [target] centering on a room temperature is set up, at an elevated temperature or low temperature, an angle of rotation shifts from a target angle of rotation to a Faraday-rotation child, and he has the problem that the performance deteriorates.
[0007] Although the Faraday-rotation child who can control a Faraday-rotation angle using an electromagnet was also proposed, the conventional Faraday-rotation child was not able to control a Faraday-rotation angle uniformly to temperature change.
[0008] Moreover, in the Faraday-rotation child by whom the conventional proposal is made, control of a Faraday-rotation angle was current control. Although it is desirable in the usual electronic circuitry that it is controllable by voltage, the armature-voltage control Faraday-rotation child is not proposed.
[0009] Therefore, the purpose of this invention is offering the Faraday-rotation child who can control a Faraday-rotation angle uniformly irrespective of temperature change. Other purposes of this invention are offering an optical device without the performance degradation which originated in change of a Faraday-rotation angle over the latus temperature requirement by controlling a Faraday-rotation angle uniformly to a temperature change.
[0010]
[Means for Solving the Problem] The magneto optics crystal which according to this invention is a Faraday-rotation child and was prepared in the propagation path of light, A magnetic field impression means containing the electromagnet which generates either the above 1st or the 2nd magnetic field at least to impress the 1st and 2nd mutually different magnetic fields of a direction to the aforementioned magneto optics crystal so that synthetic magnetic field strength may exceed a predetermined value, The driving means which drive the aforementioned electromagnet, and the temperature sensor adjoined and prepared for the aforementioned Faraday-rotation child, The data of the temperature dependence of the Faraday-rotation angle of the aforementioned magneto optics crystal are

built in, and the Faraday-rotation child characterized by providing the control means which control the aforementioned driving means so that a Faraday-rotation angle becomes fixed according to the detection temperature of the aforementioned temperature sensor is offered.

[0011] Preferably, the magnetic field impression means contains the permanent magnet which impresses another side of the 1st and 2nd magnetic fields, and the 1st and 2nd magnetic fields are impressed in the direction which intersects perpendicularly mutually in a flat surface including the propagation direction of light. Preferably, a temperature sensor is a thermistor convertible into current change about a temperature change.

[0012] The magneto optics crystal which according to other sides of this invention is a Faraday-rotation child and was prepared in the propagation path of light, The 1st permanent magnet which has the 1st temperature coefficient of magnetic field strength arranged so that the direction of a magnetic field generated to the propagation path of light may make the 1st angle, Have been arranged so that the direction of a magnetic field generated to the propagation path of light may make the 2nd bigger angle than the 1st angle of the above. The 2nd permanent magnet which has the 2nd temperature coefficient of bigger magnetic field strength than the 1st temperature coefficient of the above is provided. The Faraday-rotation child to whom the Faraday-rotation angle produced in the light which passes the aforementioned magneto optics crystal by the synthetic magnetic field of the magnetic field generated by the above 1st and the 2nd permanent magnet is characterized by being maintained at simultaneously regularity irrespective of a temperature change is offered.

[0013] Preferably, the 1st permanent magnet is arranged so that the direction of a magnetic field may become parallel to the propagation direction of light, and the 2nd permanent magnet is arranged so that the direction of a magnetic field of the 1st permanent magnet and the direction of a magnetic field may cross at right angles.

[0014] The magneto optics crystal which according to the side of further others of this invention is an optical device and was prepared in the propagation path of light, A magnetic field impression means containing the electromagnet which generates either the above 1st or the 2nd magnetic field at least to impress the 1st and 2nd mutually different magnetic fields of a direction to the aforementioned magneto optics crystal so that synthetic magnetic field strength may exceed a predetermined value, The temperature change adjoined and prepared for the Faraday-rotation child containing the driving means which drive the aforementioned electromagnet, and the aforementioned Faraday-rotation child A temperature sensor convertible into current change, The data of the temperature dependence of the Faraday-rotation angle of the aforementioned magneto optics crystal are built in, and the optical device characterized by providing the control means which control the aforementioned driving means so that a Faraday-rotation angle becomes fixed according to the detection temperature of the aforementioned temperature sensor is offered.

[0015]

[Embodiments of the Invention] Reference of drawing 1 shows the perspective diagram of the Faraday-rotation child of the 1st operation gestalt of this invention.

[0016] The Faraday-rotation child 2 contains the magneto optics crystal 4, and the permanent magnet 6 and electromagnet 8 which impress a magnetic field in the direction which intersects perpendicularly mutually to a magneto optics crystal 4. The coil 9 is wound around the electromagnet 8 and drive current is supplied to a coil 9 by the source 10 of a good transformation style.

[0017] By using the comparatively thin magneto optics crystal 4 of the thickness of sufficient grade for a light beam to penetrate, a saturation magnetic field (magnetic field strength needed for saturating the magnetic field strength which saturates magnetization of a magneto optics crystal, or a Faraday-rotation angle) can be made small.

[0018] As a magneto optics crystal 4, YIG (yttrium iron garnet) started thinly and the 3 (GdBi) 5 (FeAlGa) O12 grade which carried out the epitaxial crystal growth can be used.

[0019] The direction of the magnetic field impressed to a magneto optics crystal 4 with a permanent magnet 6 is parallel to the transparency direction of the light beam 12 in a magneto optics crystal 4, and that of the direction of the magnetic field impressed to a magneto optics crystal 4 with an electromagnet 8 is perpendicular to the magnetic field impression direction by the permanent magnet 6 in a magneto optics crystal 4, and the transparency direction of a light beam 12.

[0020] The light beam 12 which carries out incidence to a magneto optics crystal 4 is the linearly polarized light, and is made to carry out Faraday rotation of the polarization direction by the Faraday-rotation child 2. A Faraday-rotation angle changes with purposes which use the Faraday-rotation child 2, and, in the case of an optical isolator, a Faraday-rotation angle is set up by 45 degrees.

[0021] The synthetic magnetic field strength by the permanent magnet 6 and the electromagnet 8 is set up so that it may become always larger than the saturation magnetic field in a magneto optics crystal 4. the case where a magnetic field with the reason smaller than the saturation magnetic field of a magneto optics crystal 4 is impressed -- the inside of a magneto optics crystal 4 -- many magnetic domains -- being generated -- the interface between each magnetic

domain -- it is because un-arranging, such as dispersion of the light to kick, arise

[0022] In the XYZ rectangular cross three-dimensions system of coordinates used by the following explanation, the Z-axis is parallel to the propagation direction of the transmitted light of a magneto optics crystal 4, and the Y-axis is parallel to the thickness direction of a magneto optics crystal 4. That is, the direction of the impression magnetic field according to a permanent magnet 6 at this operation form is parallel to the Z-axis, and the direction of the impression magnetic field by the electromagnet 8 is parallel to the X-axis.

[0023] Drawing 2 is drawing for explaining the direction and strength (size) of magnetization in the Faraday-rotation child 2 shown in drawing 1 . [the magnetic field given to a magneto optics crystal 4 and a magneto optics crystal 4]

[0024] As now shown to a magneto optics crystal 4 by the sign 101 only with a permanent magnet 6, when the magnetic field is impressed, magnetization of a magneto optics crystal 4 becomes the Z-axis and parallel, as a sign 102 shows. The impression magnetic field strength at this time (the length of a magnetic field vector 101) is set up so that the intensity of magnetization (the length of the magnetization vector 102) of a magneto optics crystal 4 may be saturated.

[0025] If it is impressed in parallel with the X-axis as the magnetic field by the electromagnet 8 is shown by the sign 103, a synthetic magnetic field will serve as a synthetic vector of magnetic field vectors 101 and 103, as shown by the sign 104.

[0026] Magnetization as shown in a magneto optics crystal 4 with a sign 105 by this synthetic magnetic field 104 arises. The magnetization vector 105 and the magnetic field vector 104 are parallel, and length's of the magnetization vector 105 correspond with the length of the magnetization vector 102.

[0027] The degree of contribution to Faraday rotation in a magneto optics crystal 4 is not necessarily the same just because the intensity of magnetization of a magneto optics crystal 4 is fixed. It is because a Faraday-rotation angle is dependent also on the relation between the direction of the magnetization concerned, and the propagation direction of light.

[0028] Namely, if the state where the state where magnetization 102 has arisen, and magnetization 105 have arisen is compared, as for the latter Faraday-rotation angle, only the part to which the Z component 106 of magnetization 105 is decreasing to Z component (magnetization 102 itself) of magnetization 102 will become small.

[0029] If there is temperature dependence in a Faraday-rotation angle and a Faraday-rotation angle is set as a predetermined angle at a room temperature as mentioned above, at an elevated temperature or low temperature, the gap from this predetermined angle will arise and a Faraday-rotation child's performance will deteriorate.

[0030] For example, a Faraday-rotation angle becomes small, so that it becomes an elevated temperature, when YIG is adopted as a magneto optics crystal 4. The Faraday-rotation child 2 of this operation gestalt controls the current passed in the coil 9 of an electromagnet 8 according to temperature change, and a fixed Faraday-rotation angle is always acquired.

[0031] If drawing 1 is referred to again, although the sign 14 shows temperature sensors, such as a thermistor, and does not illustrate especially, the temperature sensor 12 is attached in the Faraday-rotation child 2 through a thermally conductive good material.

[0032] The detection temperature detected by the temperature sensor 14 is inputted into a controller 16. A controller 16 consists of for example, microprocessor units (MPU).

[0033] The correction value by temperature change is computed and the source 10 of a good transformation style is controlled by the controller 16 based on this correction value. The function of a controller 16 is explained with reference to the flow chart of drawing 3 .

[0034] First, a Faraday-rotation angle indication signal is inputted into a controller 16 in Step 110. For example, in using the Faraday-rotation child 2 as an optical isolator, it inputs an indication signal which serves as a 45-degree Faraday-rotation angle.

[0035] Next, the current value of a temperature sensor 14 is incorporated at Step 111, and this current value is changed into temperature data at Step 112. Standard temperature (room temperature) is lengthened from the detection temperature detected by the temperature sensor 14 at Step 113, and it asks for temperature-gradient deltaT. Correction value is computed by multiplying deltaT by a Faraday-rotation child's temperature coefficient at Step 114 (Step 115).

[0036] This Faraday-rotation child's temperature coefficient becomes settled with the matter which constitutes a magneto optics crystal, and YIG has the temperature coefficient of -0.06-degree[/degree] C. This temperature coefficient is beforehand included in the program.

[0037] After computing correction value at Step 115, it progresses to Step 116 and drive current value is computed. The relation between a Faraday-rotation angle and drive current is beforehand memorized as a table in the program.

[0038] This drive current value is inputted into a drive circuit (source 10 of a good transformation style) at Step 117, and this drive current is supplied to the coil 9 of an electromagnet 8 from the source 10 of a good transformation style.

Thus, since it was made to change the current passed in the coil 9 of an electromagnet 8 according to the temperature change detected by the temperature sensor 14, the Faraday-rotation child 2 of this operation gestalt can acquire the Faraday-rotation angle always considered as a fixed request irrespective of temperature change.
[0039] For example, in the case of 90-degree rotator, the Faraday-rotation child's 2 temperature coefficient is set to about 0.1 degree[/degree] C. Therefore, if temperature does 20 degreeC change of, about 2 degrees of Faraday-rotation angles will change. In the case of 45-degree Faraday-rotation child, if temperature does 20 degreeC change of, about 1 degree of Faraday-rotation angles will change.
[0040] Since about 36mA drive current is required to change 60 degrees of Faraday-rotation angles from the graph of drawing 4 , in order to change about 1 degree of Faraday-rotation angles, amendment of 0.6mA drive current is needed.

[0041] This amendment is incorporable into a program. If the Faraday-rotation angle is amended before computing drive current at Step 116, amendment operation can be reduced at once.
[0042] Reference of drawing 5 shows the operation gestalt at the time of using the Faraday-rotation child 2 who mentioned above for an optical attenuator. The optical attenuator 17 is arranged and constituted from the light source side which an optical fiber 18, a lens 20, the taper-like birefringence crystal 22, the Faraday-rotation child 2 who showed drawing 1 and the taper-like birefringence crystal 24, a lens 26, and an optical fiber 28 do not illustrate by this sequence.
[0043] The quality of the material of the birefringence crystals 22 and 24 is a rutile, and these configurations are the same. The field which the crowning and pars basilaris ossis occipitalis of the birefringence crystal 22 counter the pars basilaris ossis occipitalis and crowning of the birefringence crystal 24, respectively, and corresponds is mutually parallel.
[0044] Moreover, the optical axis of the birefringence crystals 22 and 24 is in a flat surface perpendicular to space, and the physical relationship of each optical axis is based on a setup of the loss at the time of the zero input of an attenuator. In the following explanation, at the time of a zero input, it supposes that it is determined that loss becomes the minimum, and the optical axis of the birefringence crystal 22 and the optical axis of the birefringence crystal 24 presuppose mutually that it is parallel.
[0045] Signs 30 are temperature sensors, such as a thermistor, and the detection temperature of a temperature sensor 30 is inputted into a controller 32, calculates change of the drive current by temperature change by the controller 32, and controls the drive circuit 34. This control method is the same as that of the control method of the Faraday-rotation child 2 who mentioned above, and an outline.
[0046] The outgoing radiation light of an optical fiber 18 is changed into a collimation beam by the lens 20, and this collimation beam disregards a beam size and is shown by the sign 36. A beam 36 is divided into the beam 38 equivalent to the ordinary ray, and the beam 40 equivalent to an extraordinary ray in the birefringence crystal 22. The polarization direction of a beam 38 and the polarization direction of a beam 40 lie at right angles mutually.
[0047] Only the respectively same angle rotates the polarization direction by the Faraday-rotation child 2, and beams 38 and 40 turn into beams 39 and 41, respectively. A beam 39 is divided into the beam 42 which is the ordinary ray component, and the beam 43 which is an extraordinary-ray component in the birefringence crystal 24. Moreover, a beam 41 is divided into the beam 44 which is the extraordinary-ray component, and the beam 45 which is a part for usual state Mitsunari in the birefringence crystal 24.
[0048] If a beam 42 or 45 takes into consideration the history of refraction, the configuration of the birefringence crystals 22 and 24, and arrangement gestalt which have been received, respectively, the beam 42 and the beam 44 are mutually parallel, and that of a beam 43 and a beam 45 are not mutually parallel. Therefore, only beams 42 and 44 can be narrowed down with a lens 26 a beam 42 or among 45, and incidence can be carried out to an optical fiber 28.
[0049] Now, the ratio of the total power of beams 42 and 44 and the total power of beams 43 and 45 is dependent on the Faraday-rotation angle in a Faraday-rotation child. Therefore, by controlling the Faraday-rotation child's 2 Faraday-rotation angle according to a target attenuation value, it can be made to be able to decrease with the attenuation factor of a request of the light beam by which outgoing radiation was carried out from the optical fiber 18, and can input into an optical fiber 28. Control of an attenuation factor is performed by adjusting the current passed in the coil of the Faraday-rotation child's 2 electromagnet by the drive circuit 34.
[0050] By the way, if temperature change arises to obtain a desired attenuation factor, the Faraday-rotation child's 2 Faraday-rotation angle cannot change, and cannot obtain a desired attenuation factor. Therefore, a temperature sensor 30 detects the Faraday-rotation child's 2 ambient temperature, and the drive current passed in the coil of an electromagnet with the software beforehand programmed according to this detection temperature is controlled by the optical attenuator of this operation gestalt.
[0051] With reference to drawing 6 , the control method of a Faraday-rotation angle according to temperature change is

explained. First, if an attenuation value is inputted into a controller 32 at Step 210, a controller 32 will compute a Faraday-rotation angle indication signal at Step 211.

[0052] Subsequently, it progresses to Step 212 and the current value detected by the temperature sensors 30, such as a thermistor, is incorporated for a controller 32. From Step 212 of this flow chart, since Step 218 is equivalent to Step 117 from Step 111 of the flow chart shown in drawing 3 , the explanation is omitted. Thus, the attenuation factor considered as a request can always be obtained irrespective of temperature change by adjusting the drive current of the Faraday-rotation child's 2 electromagnet according to temperature change.

[0053] Next, with reference to drawing 7 (A) and drawing 7 (B), the case where the Faraday-rotation child 2 is employed as an optical isolator is explained. The composition of this operation gestalt is the same on the composition of an optical attenuator shown in drawing 5 , and parenchyma. However, the Faraday-rotation child's 2 Faraday-rotation angle is set as 45 degrees, and, for this reason, it is easy to be small [the span of adjustable range of the drive current by the drive circuit 64].

[0054] The optical fiber 48 which is in the propagation direction upstream of the light of the forward direction as an optical isolator 46 is shown in drawing 7 (A), The lens 50 which uses as a collimation beam light which carried out outgoing radiation from the optical fiber 48, It has the polarizer 52 which consists of a wedge-like birefringence crystal, the Faraday-rotation child 2 by whom the angle of rotation was set as 45 degrees, the polarizer 54 which consists of a wedge-like birefringence crystal, the lens 56, and the optical fiber 58, and these components are arranged in this sequence at the travelling direction of light.

[0055] Polarizers 52 and 54 are formed so that the field where the crowning and pars basilaris ossis occipitalis of a polarizer 52 counter and correspond to the pars basilaris ossis occipitalis and crowning of a polarizer 54, respectively may become parallel mutually. Although the arrangement relation of polarizers 52 and 54 is contrary to the arrangement relation of the birefringence crystals 22 and 24 of the optical attenuator shown in drawing 5 , both of the arrangement relations are employable.

[0056] 45 degrees of opticals axis of a polarizer 54 are rotated to the optical axis of a polarizer 52 in the same direction as the direction of the rotatory polarization in the Faraday-rotation child 2. And when the light of the forward direction from an optical fiber 48 passes a lens 50, a polarizer 52, the Faraday-rotation child 2, and a polarizer 54 in this sequence and connects a focus with a lens 56, it is set up so that this focus may be located in the core end face of an optical fiber 58.

[0057] Furthermore, when the light of the opposite direction from an optical fiber 58 passes a lens 56, a polarizer 54, the Faraday-rotation child 2, and a polarizer 52 in this sequence and connects a focus with a lens 50, it is made for this focus to be located out of the core end face of an optical fiber 48.

[0058] Since the refractive index in a polarizer 52 changes with polarization components when the beam which carried out the deer, carried out outgoing radiation from the optical fiber 48, and was collimated with the lens 50 carries out incidence to a polarizer 52 with the forward direction, an incident light is divided into an ordinary ray and an extraordinary ray, is refracted in another direction, and carries out incidence to the Faraday-rotation child 2.

[0059] Since 45 degrees of opticals axis of a polarizer 54 are rotated to the optical axis of a polarizer 52 in the same direction as the direction of the rotatory polarization in the Faraday-rotation child 2, by the Faraday-rotation child 2, 45-degree rotatory polarization of the ordinary ray and extraordinary ray in a polarizer 52 is carried out, respectively, and they turn into an ordinary ray and an extraordinary ray also in a polarizer 54, respectively.

[0060] Therefore, the ordinary ray and extraordinary ray which penetrated the polarizer 54 become parallel mutually, and outgoing radiation is carried out. It converges with a lens 56 and incidence of the collimation beam of this ordinary ray and an extraordinary ray is carried out to an optical fiber 58.

[0061] As shown in drawing 7 (B), after carrying out incidence to a polarizer 54, the reflective feedback light reflected by the optical connecter end face which is not illustrated on the other hand is divided into an ordinary ray and an extraordinary ray, is refracted in another direction, carries out incidence to the Faraday-rotation child 2, is rotated 45 degrees and carries out outgoing radiation of the plane of polarization.

[0062] The ordinary ray in the polarizer 54 which 45 degrees of plane of polarization rotated receives the refraction as an extraordinary ray in a polarizer 52. Moreover, the extraordinary ray in the polarizer 54 which 45 degrees of plane of polarization rotated receives the refraction as an extraordinary ray in a polarizer 52.

[0063] Therefore, the travelling direction of the light which carries out outgoing radiation to an opposite direction from a polarizer 52 differs from the travelling direction of the light of the forward direction. Therefore, in the light of an opposite direction, even if it passes a lens 50, this light is not combined with an optical fiber 48.

[0064] By the way, as mentioned above, this angle of rotation cannot change and the Faraday-rotation child's 2 Faraday-rotation angle cannot realize the optical isolator of sufficient extinction ratio, if temperature is changed, when it changes with temperature and the Faraday-rotation child's 2 angle of rotation is set as 45 degrees in a room

temperature.
[0065] Therefore, in the optical isolator 46 of this operation gestalt, a temperature sensor 60 detects the Faraday-rotation child's 2 ambient temperature, and this detection temperature is inputted into a controller 62.
[0066] As mentioned above, the correction value of drive current is computed according to detection temperature, based on this correction value, the drive circuit 64 is controlled by the controller 62, and even if temperature changes, the drive current passed in the coil of an electromagnet so that a Faraday-rotation angle may always become 45 degrees is adjusted.
[0067] Next, the operation gestalt at the time of using the Faraday-rotation child 2 for an optical switch 75 with reference to drawing 8 and drawing 9 is explained. In drawing 8 , 1/2 wavelength plate in which signs 76 and 78 were formed from crystal, and 80 and 82 are plate-like birefringent plates, such as a calcite or a rutile.
[0068] The birefringent plate 80 is inserted among the polarizing prisms 86 and the Faraday-rotation children 2 who have the polarization demarcation membrane 84. 1/2 wavelength plate 76 is inserted so that the lower part portion of a birefringent plate 80 may be countered between a polarizing prism 86 and a birefringent plate 80.
[0069] The birefringent plate 82 is inserted between the polarizing prisms 90 which have the polarization demarcation membrane 88 with the Faraday-rotation child 2. 1/2 wavelength plate 78 is inserted so that the upper part portion of a birefringent plate 82 may be countered between a polarizing prism 90 and a birefringent plate 82.
[0070] When the magnetic field impressed is the same as that of the travelling direction of light, the Faraday-rotation child 2 rotates 45 degrees of plane of polarization in the direction of the circumference of a clock, and, as for the case of an opposite direction, rotates 45 degrees of plane of polarization to the circumference of an anti-clock. Moreover, 1/2 wavelength plate 92 always rotates 45 degrees of plane of polarization in the direction of the circumference of an anti-clock.
[0071] If the magnetic field impressed to the Faraday-rotation child 2 is carried out in the direction of an arrow and incidence of the light beam 126 is now carried out to a polarizing prism 86 from an optical fiber 94, a light beam 126 will be separated into the P polarization 128 and the S polarization 132 by the polarizing prism 86.
[0072] In case 90 degrees of plane of polarization rotate, and it turns into S polarization, in case the P polarization 128 passes 1/2 wavelength plate 76, and it passes birefringent plates 80 and 82 further, as the crosstalk component resulting from the polarization demarcation membrane 84 shows by the dotted line, it is refracted, and produces an advancing-side-by-side gap.
[0073] On the other hand, in case the S polarization 130 passes birefringent plates 80 and 82, as the crosstalk component resulting from the polarization demarcation membrane 84 shows by the dotted line, it is refracted, and causes an advancing-side-by-side gap. Furthermore, in case 1/2 wavelength plate 78 is passed, 90 degrees of plane of polarization rotate, and it serves as P polarization.
[0074] Therefore, since P polarization passes the polarization demarcation membrane 88 and S polarization is reflected by the polarization demarcation membrane 88, almost all light is compounded as a light beam 132, and is combined with an optical fiber 96.
[0075] Since the crosstalk component shown on the other hand by the dotted line by which outgoing radiation is carried out to the upper part from a polarizing prism 90 has caused the advancing-side-by-side gap as mentioned above, it is not combined with an optical fiber 98.
[0076] Since the Faraday-rotation child's 2 direction of the rotatory polarization and the direction of the rotatory polarization of 1/2 wavelength plate 92 turn into an opposite direction mutually and the rotatory polarization is offset when the Faraday-rotation child's 2 direction of an impression magnetic field is the direction of an illustration arrow, in being drawing 8 , when a light beam passes the Faraday-rotation child 2 and 1/2 wavelength plate 92, it does not influence the plane of polarization at all.
[0077] Next, although the P polarization 128 and the S polarization 130 which were separated with the polarizing prism 86 are the same as that of the state of drawing 8 until they pass a birefringent plate 80 if the direction of a magnetic field impressed to the Faraday-rotation child 2 is made into the impression direction and opposite direction of drawing 8 as shown in drawing 9 , and incidence of the light beam 126 is carried out to a polarizing prism 86 from an optical fiber 94, in case the Faraday-rotation child 2 and 1/2 wavelength plate 92 are passed, 90 degrees of the plane of polarization rotate.
[0078] Therefore, if outgoing radiation is carried out from 1/2 wavelength plate 92, although the P polarization 128 is still P polarization, the S polarization 130 will turn into P polarization. The crosstalk component and optical path of light which carried out outgoing radiation from 1/2 wavelength plate 92 which are refracted in case a birefringent plate 82 is passed, and are shown by the dotted line correspond.
[0079] Then, 90 degrees of plane of polarization rotate, and P polarization which passes 1/2 wavelength plate 78 turns into S polarization, and is reflected by the polarization demarcation membrane 88 of a polarizing prism 90. On the

other hand, P polarization passes the polarization demarcation membrane 88, and a composite beam 134 is combined with an optical fiber 98. On the other hand, since the crosstalk component shown by the dotted line which carries out outgoing radiation rightward has started the advancing-side-by-side gap from the polarizing prism 90, it is not combined with an optical fiber 96.

[0080] As explained above, even if crosstalk of the polarization demarcation membranes 84 and 88 is large, a crosstalk component is not combined with optical fibers 96 and 98, and crosstalk of an optical switch can be reduced.

[0081] However, as mentioned above, the Faraday-rotation child's 2 angle of rotation changes with temperature change. Therefore, when temperature changes, the crosstalk component resulting from change of a Faraday-rotation angle will occur.

[0082] Therefore, in the optical switch 75 of this operation gestalt, the Faraday-rotation child's 2 temperature is detected by the temperature sensor 120, and this detection temperature is inputted into a controller 122. By the controller 122, as mentioned above, the correction value resulting from temperature change is calculated, and the drive current based on this correction value is computed.

[0083] By supplying the drive current computed by having carried out in this way in the Faraday-rotation child's 2 coil, a fixed Faraday-rotation angle can always be acquired irrespective of temperature change. Thereby, crosstalk resulting from change of a Faraday-rotation angle can be reduced.

[0084] Next, with reference to drawing 10 , the Faraday-rotation child 66 of the 2nd operation gestalt of this invention is explained. The Faraday-rotation child 66 consists of magneto optics crystals 68, such as YIG, the 1st permanent magnet 70 arranged so that the direction of a magnetic field generated to the propagation path of a light beam 74 may make the 1st angle, and the 2nd permanent magnet 72 arranged so that the direction of a magnetic field generated to the propagation path of a light beam 74 may make the 2nd bigger angle than the 1st angle.

[0085] With this operation gestalt, the 1st permanent magnet 70 is arranged so that the direction of a magnetic field may become parallel to the propagation direction of a light beam 74, and the 2nd permanent magnet 72 is arranged so that the direction of a magnetic field of the 1st permanent magnet 70 and the direction of a magnetic field may cross at right angles.

[0086] In the Faraday-rotation child 66 of this operation gestalt, with two permanent magnets 70 and 72, a magnetic field is impressed to a magneto optics crystal 68, and a Faraday-rotation angle changes according to the angle which the direction of a synthetic magnetic field makes with the propagation direction of a light beam 74. Generally the magnetism of a permanent magnet is changed with temperature.

[0087] In the Faraday-rotation child 66 of this operation gestalt, since two permanent magnets 70 and 72 are used, the factors which change a Faraday-rotation angle are change of the direction of a synthetic magnetic field by permanent magnets 70 and 72, and the physical properties of the magneto optics crystal which changes according to temperature change. The way which becomes settled by physical properties between these two factors cannot usually be adjusted.

[0088] However, change of the direction of a synthetic magnetic field can be adjusted according to the quality of the material and structure of a yoke of leading the magnetic field generated with how to combine two permanent magnets 70 and 72 and permanent magnets 70 and 72 to a magneto optics crystal 68. For example, generally, if a permanent magnet becomes an elevated temperature, there will be many to which magnetism becomes weak and the temperature coefficient of magnetic field strength will be determined by magnetic composition.

[0089] Moreover, a magneto optics crystal has many to which a Faraday-rotation angle will become small if it becomes an elevated temperature, and the temperature coefficient of a Faraday-rotation angle changes with physical properties of a magneto optics crystal. Since a practical magneto optics crystal has the narrow width of face of selection, it is almost impossible to attain the temperature coefficient of a desired Faraday-rotation angle with a magneto-optics-crystal simple substance. However, the temperature coefficient of a desired Faraday-rotation angle can be attained by using the permanent magnets 70 and 72 which have a different property.

[0090] In the Faraday-rotation child 66 who showed drawing 10 , the 1st permanent magnet 70 shall be made from the material which the temperature coefficient of magnetic field strength can disregard small. For example, the 1st permanent magnet 70 is formed from Sm-Co system material.

[0091] The 2nd permanent magnet 72 shall be made from the material from which magnetic field strength falls, if the temperature coefficient of magnetic field strength is large and becomes an elevated temperature. For example, the 2nd permanent magnet 72 is formed from NdFeB system material.

[0092] On the other hand, if a magneto optics crystal 68 generally becomes an elevated temperature, a Faraday-rotation angle will become small. For example, in YIG, whenever temperature does 1 degreeC elevation of, a Faraday-rotation angle decreases by about 0.06 degrees. Even if the Faraday-rotation child 66 of this operation gestalt has temperature change, he can maintain a Faraday-rotation angle almost uniformly.

[0093] With reference to drawing 11 , an operation of the Faraday-rotation child 66 of this operation gestalt is

explained. The magnetic field strength of the 1st permanent magnet 70 is A, and even if there is temperature change, the magnetic field strength is simultaneously regularity. Moreover, the direction of a magnetic field of the 1st permanent magnet 70 is parallel to the propagation direction of a light beam 74.

[0094] on the other hand -- the state of ordinary temperature -- the magnetic field strength of the 2nd permanent magnet 72 -- B-2 it is -- the angle of the direction of a synthetic magnetic field and the direction of a magnetic field of the 1st permanent magnet 70 to make is theta 2 The Faraday-rotation angle in this case is set to thetaF costheta2 when a Faraday-rotation angle when the direction of a magnetic field is in agreement with the travelling direction of light is set to thetaF.

[0095] When it becomes an elevated temperature, the magnetic field strength of the 2nd permanent magnet 72 is B1. It decreases. Therefore, the angle which the direction of a synthetic magnetic field and the direction of a magnetic field of the 1st permanent magnet 70 make is set to theta 1 [smaller than theta 2]. Therefore, the Faraday-rotation angle at this time is set to thetaF costheta1, and thetaF becomes larger uniformly then than thetaF costheta2.

[0096] However, since the magneto optics crystal 68 to which a Faraday-rotation angle becomes small will be used if it becomes an elevated temperature, if thetaF becomes an elevated temperature, it will become small. Therefore, the effect which the direction of the synthetic magnetic field of two permanent magnets 70 and 72 gives to Faraday rotation, and the effect of the temperature coefficient of a magneto optics crystal 68 are committed to opposite direction.

[0097] Therefore, change of the direction of the synthetic magnetic field of two permanent magnets 70 and 72 can offset the influence which temperature change has on Faraday rotation of a magneto optics crystal 68 under the influence which it has on Faraday rotation by adopting the permanent magnet which gives suitable theta1 and suitable theta2.

[0098] If the yoke of a soft magnetic material is arranged between permanent magnets 70 and 72 and a magneto optics crystal 68, adjustment of the temperature coefficient of Faraday rotation is possible by choosing suitably the quality of the material of a soft magnetic material.

[0099] By choosing suitably the quality of the material of a magneto optics crystal 68 and permanent magnets 70 and 72, it is possible to set the temperature coefficient of a Faraday-rotation angle as a desired size, and it can apply to the optical device which needs to change a Faraday-rotation angle according to temperature.

[0100] Reference of drawing 12 shows the block diagram of the 2nd operation gestalt of an optical attenuator. The voltage-current conversion circuit 144 is formed in the housing 142 of the current drive light attenuator 140. The optical attenuator 140 is driven by this voltage-current conversion circuit 144.

[0101] Although an optical attenuator is used for adjustment of the quantity of light inside a light amplifier etc., many of the control signal for adjustment are voltage signals. Then, as for control of an optical attenuator, it is desirable that it is controllable by the voltage signal. The control signal terminal 146, the power terminal 148, and the grounding terminal 150 are formed in housing 142. The sign 152 shows the light beam.

[0102] With reference to drawing 13 , the operation gestalt of the voltage-current conversion circuit 144 is explained. The control signal input terminal 146 is connected to the non-inverter input edge 164 of an operational amplifier 160.

[0103] Resistance 168 is inserted between the antiphase input edge 166 of an operational amplifier 160, and the outgoing end of an operational amplifier 160, the antiphase input edge 166 of an operational amplifier 160 minds resistance 170 further, and it is pulldown ********** to grounding potential.

[0104] The output of an operational amplifier 160 controls the drive current which the base of a transistor 172 is supplied and is supplied to the coil 176 of a Faraday-rotation child's electromagnet 174 according to the size of base voltage.

[0105] Although the above explanation explained the example which applied the Faraday-rotation child 2 who showed drawing 1 to the optical attenuator, the optical isolator, and the optical switch, the application of this invention is not limited to this and can be applied like other optical devices which use a Faraday-rotation child, such as an optical circulator and a polarization controller.

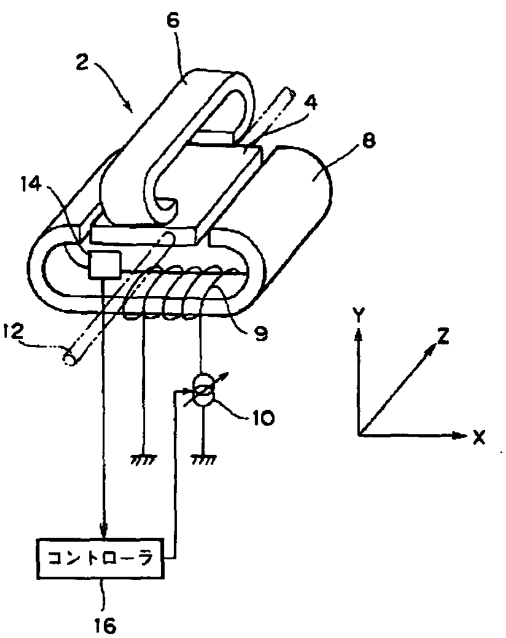
[0106]

[Effect of the Invention] According to this invention, the Faraday-rotation child who can always control a Faraday-rotation angle uniformly can be offered irrespective of temperature change. Thereby, improvement in a performance of the optical device using the Faraday-rotation child can be aimed at.

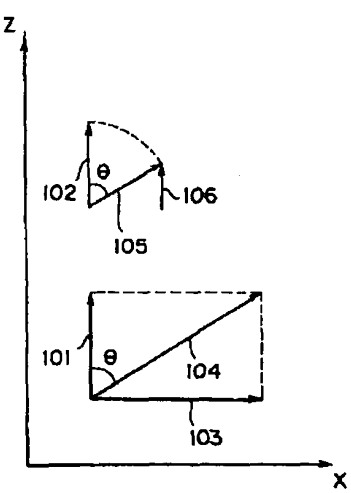
[Translation done.]

DRAWINGS

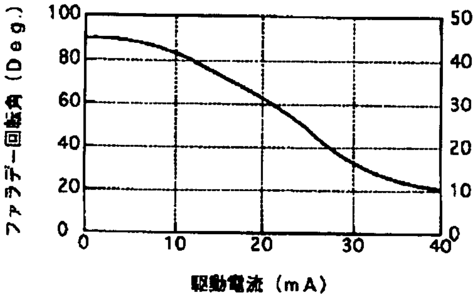
[Drawing 1]
ファラデー回転子斜視図



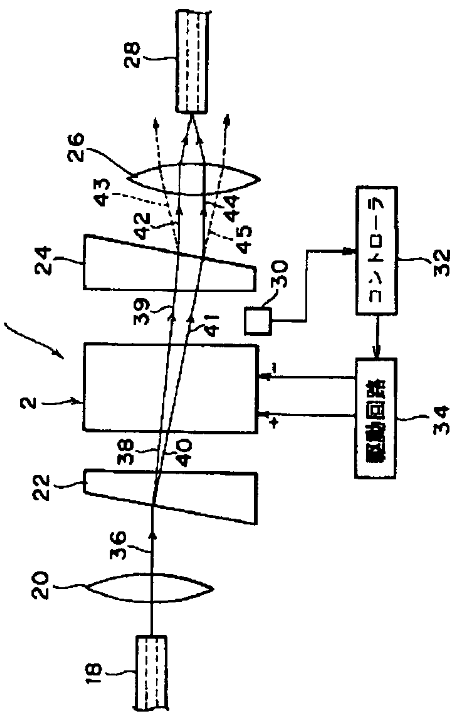
[Drawing 2]
図1における磁界及び磁化の説明図



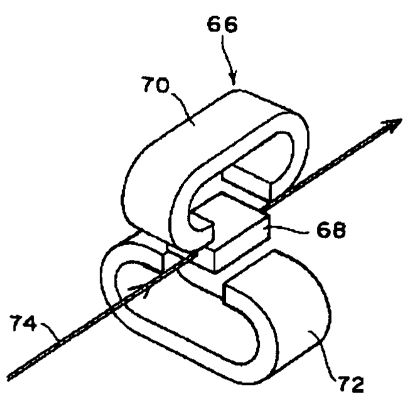
[Drawing 4]
駆動電流とファラデー回転角との関係を示すグラフ



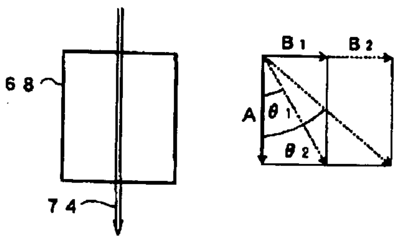
[Drawing 5]
光アッテネータ



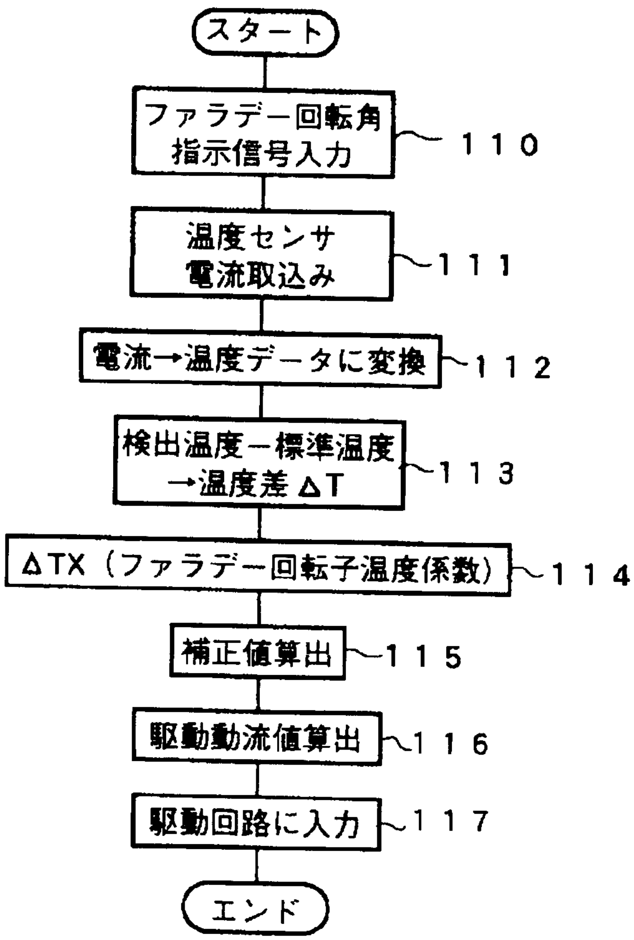
[Drawing 10]
ファラデー回転子



[Drawing 11]
温度変化と合成磁界の関係を示す図

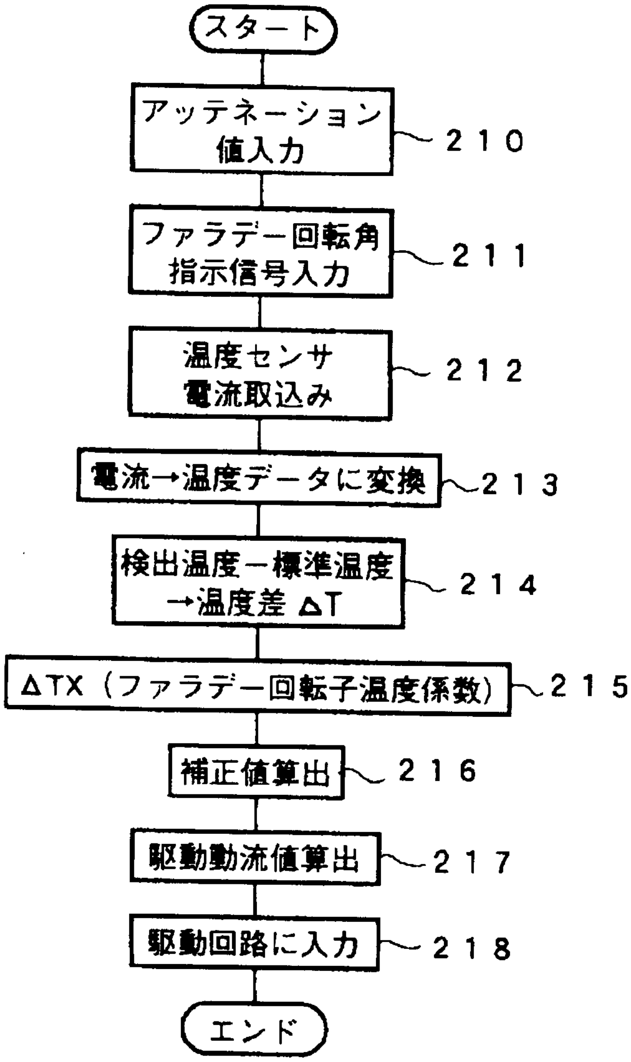


[Drawing 3]
制御フローチャート



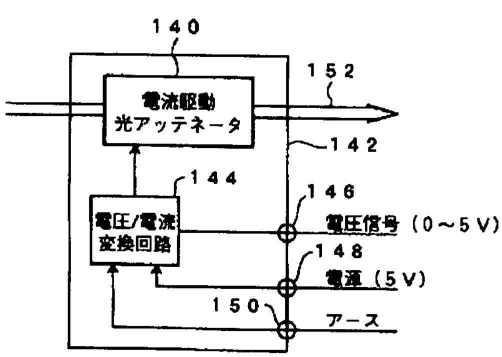
[Drawing 6]

制御フローチャート

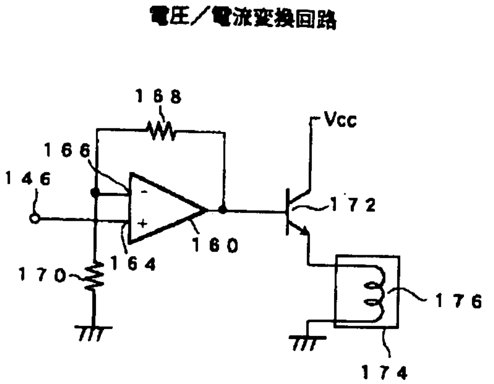


[Drawing 12]

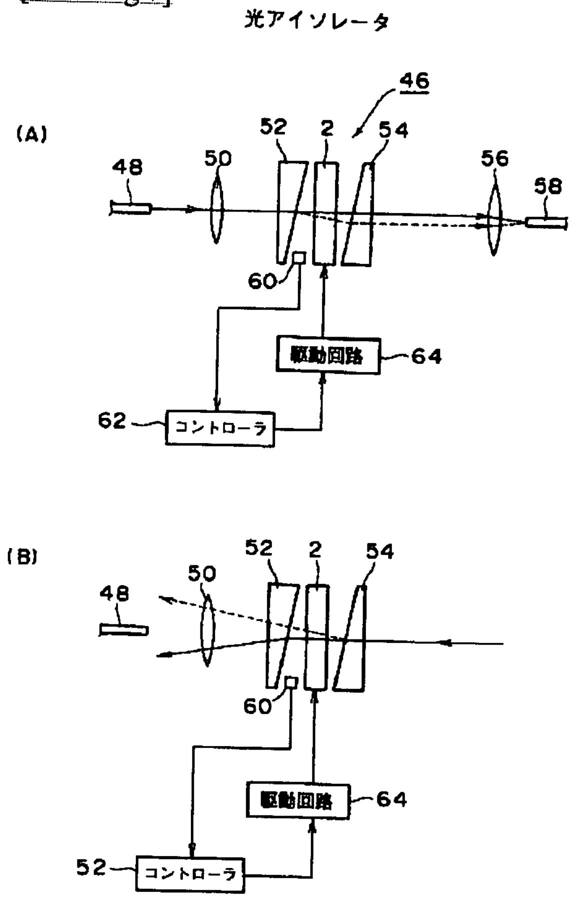
光アッテネータの第２実施形態



[Drawing 13]

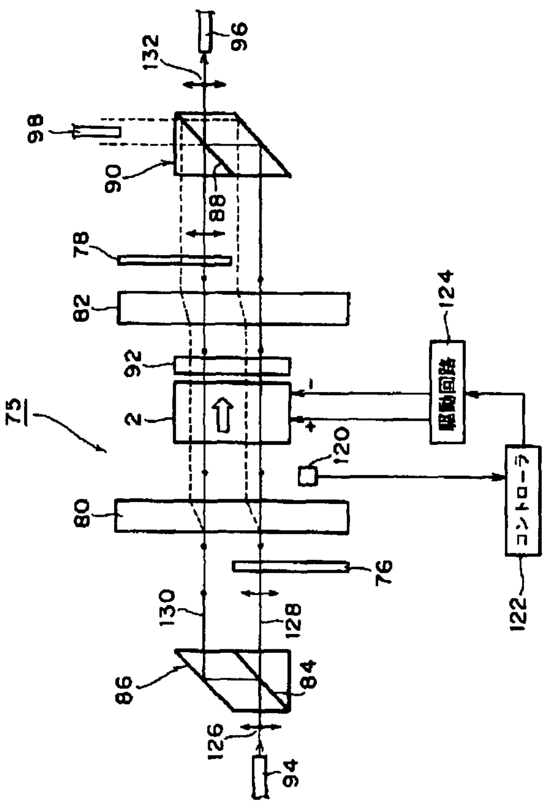


[Drawing 7]



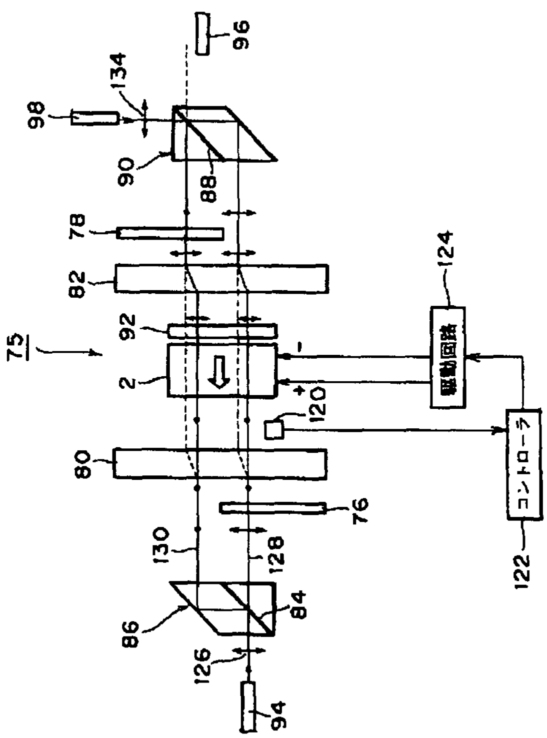
[Drawing 8]

光スイッチ



[Drawing 9]

光スイッチ



[Translation done.]